Biological Resources

Middle and Late Holocene Packrat Middens from Capitol Reef National Park

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Abstract. Twenty Holocene and two late Wisconsinan packrat middens were collected and analyzed from Capitol Reef National Park. The two older middens, collected at 1390 m elevation, were greater than 26,000 years in age and contained species typical of much higher elevations, such as Douglas fir, limber pine, Rocky Mountain juniper, and Knowlton hophornbeam. These ancient middens demonstrate the antiquity of many inaccessible deposits high in the Navajo Sandstone.

Nine Holocene middens were collected from Hall's Canyon, eight from the Hartnet Draw area, and three from other locations. A comparison of the middle and late Holocene middens to five modern middens and to modern vegetation suggests that vegetation changes taking place in the last several hundred years are more extreme than any changes occurring since at least the middle Holocene. The nature and timing of these changes imply that they were primarily caused by nineteenth century open-land sheep grazing.

Presettlement middens consistently contained abundant macrofossils of plant species palatable to large herbivores that are now absent or reduced, such as winterfat (*Ceratoides lanata*) and ricegrass (*Stipa hymenoides*), especially in the most complete series at Hartnet Draw. Macrofossils and pollen of pinyon pine (*Pinus edulis*), sagebrush (*Artemisia* spp.) and roundleaf buffaloberry (*Sheperdia rotundifolia*) were also recently reduced to their lowest levels for the 5400 year record. Conversely, species typical of overgrazed range, such as snakeweed (*Gutterrezia sarothrae*), viscid rabbitbrush (*Chrysothamnus*

visidiflorus), and Russian thistle (*Salsola* sp.) were not recorded prior to the historic introduction of grazing animals. Pollen of Utah juniper (*Juniperus osteosperma*) also increased during the last 200 years, possibly due to the elimination of grassland fires.

Key words: Holocene vegetation history, grazing impacts, packrat middens, fossil pollen, presettlement vegetation

INTRODUCTION

The purpose of this study is to produce a vegetation history of Capitol Reef National Park, reconstructing past changes in vegetation, especially those accompanying the settlement era. A reconstruction of the presettlement vegetation, existing just prior to settlement of the area by European industrialized society, was needed by the National Park in order to set restoration guidelines. Also, a reconstruction of any vegetation changes brought about by settlement impacts was needed to understand the dynamics of ecosystem change in order to better manage the park. Among the methods of reconstructing this past vegetation were an analysis of fossil packrat middens (reported here) and a study of buried plant phytoliths (Fisher et al. 1995).

Reconstructing Past Vegetation with Packrat Middens

Fossil packrat middens are valuable sources of paleoecological information in arid regions of the southwestern United States (Cole 1990, Betancourt et al. 1990). Plant macrofossils in packrat middens are often identifiable to the species level and represent species that grew close to the midden location, most likely within 50 m. Because plant identification and location can be precisely known, this method has extremely high spatial and taxonomic resolution compared to other methods of reconstructing past vegetation.

Studies comparing trees and shrubs at midden sites with plant specimens from modern middens typically report similarities exceeding 80% using a Sorensen's Index of Similarity (Spaulding et al. 1990, Frase and Sera 1993, Cole and Webb 1985, Cole 1985). This is especially true when small macrofossils (< 2 mm) are identified using a 10X microscope. Similarity with forbs and grasses has been reported to be lower (Frase and Sera 1993), but inventories of current forbs are usually incomplete due to seasonal and yearly variability in the forb flora, and identification of diverse forbs and grasses within midden assemblages is difficult.

Fossil pollen within the middens can also be analyzed (King and Van Devender 1977, Thompson 1985, Davis and Anderson 1988), emphasizing different types of vegetation, and representing a larger source area than the plant macrofossils. Interpretation of the fossil pollen abundances, like the macrofossil abundances, requires caution and experience, as some species are better represented than others. Through the consideration of both the macrofossil and pollen records, a more comprehensive understanding of past environments can be achieved.

Grazing History of Capitol Reef National Park

Settlement impacts to the vegetation of Capitol Reef can be attributed mainly to grazing by large introduced herbivores, because this was the primary economic use of these lands. Native large herbivores which may have been present in the study area during the last 5000 years include: bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), and possibly bison (*Bison bison*) and elk (*Cervus elaphus*) (Van Gelder 1928, Mead et al. 1991). Eurasian horses and asses (*Equus* spp.) were introduced to New Mexico by Spanish colonists as early as 1598 AD (Underhill 1971). By the late 1600's, feral horses were reported in parts of the west, but it is unlikely that they existed in the study area prior to the 1800's.

In the late 1800's introduced large herbivore populations increased dramatically in southern Utah with the widespread increase in open-land grazing. Livestock grazing within and near Capitol Reef National Park has been documented since at least the 1870's (Frye 1995). By 1909, more quantitative herbivore population estimates for the Capitol Reef area can be made using grazing permits issued for Powell (now part of Dixie) National Forest (Frye 1995). In 1909 the Forest Service issued summer grazing permits for 67,000 sheep and 11,000 cattle. The animals that grazed in these high summer pastures presumably spent the winter in the lower adjacent areas of Capitol Reef National Park.

A Bureau of Land Management survey described past use at the Hartnet Draw site:

> "Prior to the passage of the Taylor Grazing act in 1934, large numbers of livestock were brought from Wayne, Seiver, and Emery Counties to winter on these lands. Many of the animals remained on the range year-long, resulting in the progressive destruction of soils and vegetation. Reports from stockmen in the area indicate that many trespass horses used the area until about 1955. Prior to 1946 there were at least 163 cattle and 20 horses year-long in this area" (Hartnet Allotment File 1966).

MATERIALS AND METHODS

Approximately 1 kg of each midden was separated from the *in situ* larger masses using a hammer and chisel. In the laboratory, these 1 kg samples were then dissected producing horizontally stratified sub-samples typically measuring about 15 x 20 cm with a thickness of several centimeters. This midden sample is smaller than what is often used by some other investigators. But, it is of sufficient size to yield a full spectrum of identifiable plant macrofossils while minimizing the opportunity for intermixing of layers.

Weathering rinds and large rocks were removed from each subsample, yielding 300 to 600 g of the hardened midden material. This sample was then weighed and disaggregated in water. Pollen samples were taken from the wash water after several days of soaking, and processed using standard methods (Faegri and Iversen 1975, Murray 1989).

Plant, vertebrate, and invertebrate fossils, fecal pellets, and rocks were separated from the dissolved middens with a 1 mm sieve. The resulting matrix was dried and weighed, yielding 100 to 200 g of washed midden matrix. The dried matrix was sorted by hand under a 10X dissecting microscope. Packrat fecal pellets and rocks were removed and weighed. Identifiable plant macrofossils, vertebrate bones, and insect fossils were identified, counted, labeled, and stored in plastic vials.

Packrat fecal pellets were submitted to radiocarbon laboratories for dating. Calendar year ranges for the radiocarbon ages were calculated using the calibration program of Stuiver and Reimer (1993). Some undated middens were considered modern because of the presence of green leafy material, cow feces, and, in one sample, a peanut shell.

Data on midden contents were quantified by number and $\log_{10}$ of macrofossil concentration in midden matrix. In order to compensate for variability between middens, midden matrix weights were adjusted by subtracting the weight of the rocks and pellets from the dried washed matrix weight before calculation of the concentration. Using $\log_{10}$ of macrofossil concentration calculates a number similar to the semi-quantitative abundance scale used by several other authors, but has the advantage of being quantitative, allowing better comparisons between middens of differing size.

RESULTS

Midden dating

The ages of 22 middens ranged from 0 to greater than 39,600 yr B.P. (Table 1). One of the four collections of modern debris (containing loose green plant matter) was radiocarbon dated and found to contain

Table 1. Ages of middens based upon radiocarbon dates. Radiocarbon ages are calibrated to calendar years based upon Stuiver and Reimer (1993). Age classes are: PO=Postsettlement midden, TR=Transitional midden, PR=Presettlement midden. Probability of dating to post-1870 AD (at one sigma, extrapolated from Stuiver and Reimer 1993) shown in parentheses, PMC=Percent modern carbon (sample post-dates atmospheric testing of nuclear weapons). Modern debris was not dated except for Hartnet Draw #3. All dates except Hartnet Draw #5 (dated on *Pinus edulis* needles) are from *Neotoma* pellets.

Sample Name	Conventional Date (Probability of Dating to Postsettlement Period)	δ^{13} C	Lab ID No.	Calibrated Calendar Range	Class
LOWER HALL CANYON					
Baker Shelter #1	Modern Debris				PO
Narrows #5	Modern Debris				PO
Baker Shelter #3	20 ±80 (40%)	-24.0	A-5200	1693-1922 AD	TR
Hall Canyon #4	80 ±100 (33%)	-22.0	A-5202	1681-1940 AD	TR
Hall Canyon #6	105 ±70 (31%)	-22.5	GX-16779	1672-1955 AD	TR
Hall Canyon #7	170 ±100 (17%)	-12.5	GX-15551	1640-1955 AD	TR
Hall Canyon #8	265 ±100 (5%)	-21.5	GX-15552	1490-1954 AD	PR
Narrows #2	330 ±100	-27.2	A-5201	1450-1650 AD	PR
Baker Shelter #2	410 ±50	-22.9	A-5199	1438-1609 AD	PR
Hall Canyon #2b	28,050 ±2600	-21.4	GX-15399		PR
Hall Canyon #2a	>39,600	-22.9	GX-15400		PR
UPPER HARTNET DRAW					
Hartnet Draw #3	137 ±1.2 PMC	-22.2	A-5197	1950-1986 AD	PO
Hartnet Draw #2	330 ±60	-21.8	A-5204	1490-1637 AD	PR
Hartnet Draw #8	630 ±100	-21.2	GX-16259	1280-1410 AD	PR
Hartnet Draw #1A	1020 ±70	-21.7	A-5203	898-1152 AD	PR
Hartnet Draw #7b	1275 ±110	-20.8	GX-15554	640-890 AD	PR
Hartnet Draw #9	2570 ±135	-21.8	GX-15553	889-434 BC	PR
Hartnet Draw #5*	3615 ±70		AA-6447*	2128-1889 BC	PR
Hartnet Draw #6	5450 ±90	-21.8	A-5205	4363-4235 BC	PR
OTHER LOCATIONS					
Long Leaf Flat #1A	Modern Debris				PO
Long Leaf Flat #1B	1030 ±80	-23.4	A-5198	901-1148 AD	PR
Fremont River #1	7010 ±105	-25.3	GX-15550	5980-5740 BC	PR

* Tandem Accelerator Mass Spectrometer Date on *Pinus edulis* needles. Original unlikely date of 142 PMC on pellets is probably a lab error, sample contamination with artificial carbon isotopes, or a mislabeled sample.

137 percent modern carbon ("modern" is defined as 1950 AD levels). Thus, it post-dates the atmospheric testing of nuclear weapons.

Because of changes in the ratio of carbon isotopes in the atmosphere during the late Holocene, radiocarbon dates must be calibrated to calendar years to be correlated with historical events. The radiocarbon ages for this report have been converted to calendar years based on the calibration program of Stuiver and Reimer (1993) (Table 1). Unfortunately, because of the burning of fossil fuels, radiocarbon dates under 300 years can often represent several different time intervals during this period, and it may not be possible to determine the true age using existing methods.

In order to determine which middens dated prior to 1870 AD, which is approximately when settlement began in earnest, the probability distribution of the radiocarbon ages under 300 years was assessed. Middens that dated before 1870 AD were separated from those that dated after 1870 AD. Middens with significant possibilities of dating to both before and after 1870 AD (at one standard deviation) were placed into a third transitional group. This age assessment placed middens in one of three age categories; Presettlement (prior to 1870 AD), Postsettlement (after 1870 AD), and Transitional (dating range extending to before and after 1870 AD; possibly constructed throughout the settlement period). These determinations account for only one standard deviation (65% of the possible ages) on the measurement of ^{14}C activity in the sample, and do not account for the time span represented by the midden itself or other errors or contaminations that could have occurred before the radioactivity was measured. The amount of time that the packrat requires to construct the midden (the time period represented in the deposit) is variable, but is usually small when compared to the uncertainty associated with the radiocarbon date, especially in small samples such as these.

Hartnet Draw Site

Seven fossil and two modern middens were collected from Hartnet Draw in northern Capitol Reef National Park (Cole et al. 1997, Cole 1992). This site (38° 15' N, 111° 20' W; Fig. 1), at 1920 m elevation in Wayne County, Utah, was chosen because of its abundance of fossil packrat middens and remote location, free from most anthropogenic disturbances other than grazing.

The most abundant plant species at the site today are: Utah juniper (*Juniperus osteosperma*), Bigelow sagebrush (*Artemisia biglovii*), big sagebrush (*A. tridentata*), snakeweed (*Gutierrezia sarothrae*), Torrey ephedra (*Ephedra torreyana*), viscid rabbitbrush (*Chrysothamnus visidiflorus*), and central pricklypear (*Opuntia polyacantha*). Low areas with thicker soil support a sparse growth of the grasses: ricegrass, sand dropseed (*Sporobolus cryptandrus*), and blue grama (*Bouteloua gracilis*).

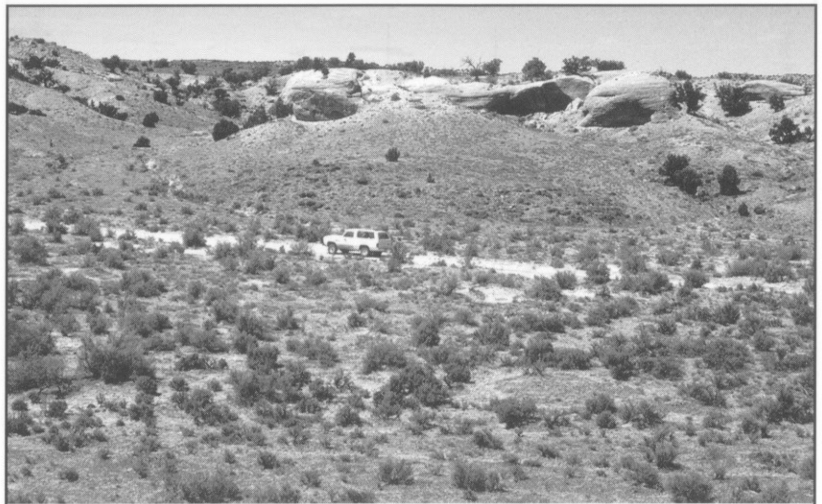

Figure 1. View of Hartnet Draw midden site. Middens were collected from small alcoves in distance.

The nine Hartnet Draw middens ranged in age from modern to 5450 yr B.P. (Table 1). The results of the macrofossil analysis for major species from the Hartnet draw middens are shown in Figure 2. The complete macrofossil data from these middens can be found in Cole et al. (1997) or Cole (1992). All of the Hartnet Draw middens contain abundant macrofossils of Utah juniper, saltbush (*Atriplex* spp.), cliff rose (*Cowania mexicana*), and prickly pear (*Opuntia* sp.), which are all abundant at the site today (Fig. 2). The presettlement middens also contain pinyon pine (*Pinus edulis*), winterfat (*Ceratoides lanata*), sagebrush (*Artemisia* sp.) and ricegrass (*Stipa hymenoides*) which are absent from the one modern midden analyzed for macrofossils (Hartnet #3). Winterfat was not observed during the field work and pinyon pine was rare in the area. The rarity or absence of sagebrush and ricegrass from the modern midden suggests that they are less common now than prior to settlement. Similarly, globe mallow (*Sphaeralcea* sp.), needlegrass (*Stipa* sp.), blue gramma (*Bouteloua gracilis*), dropseed (*Sporabolis cryptandrus*), and roundleaf buffaloberry

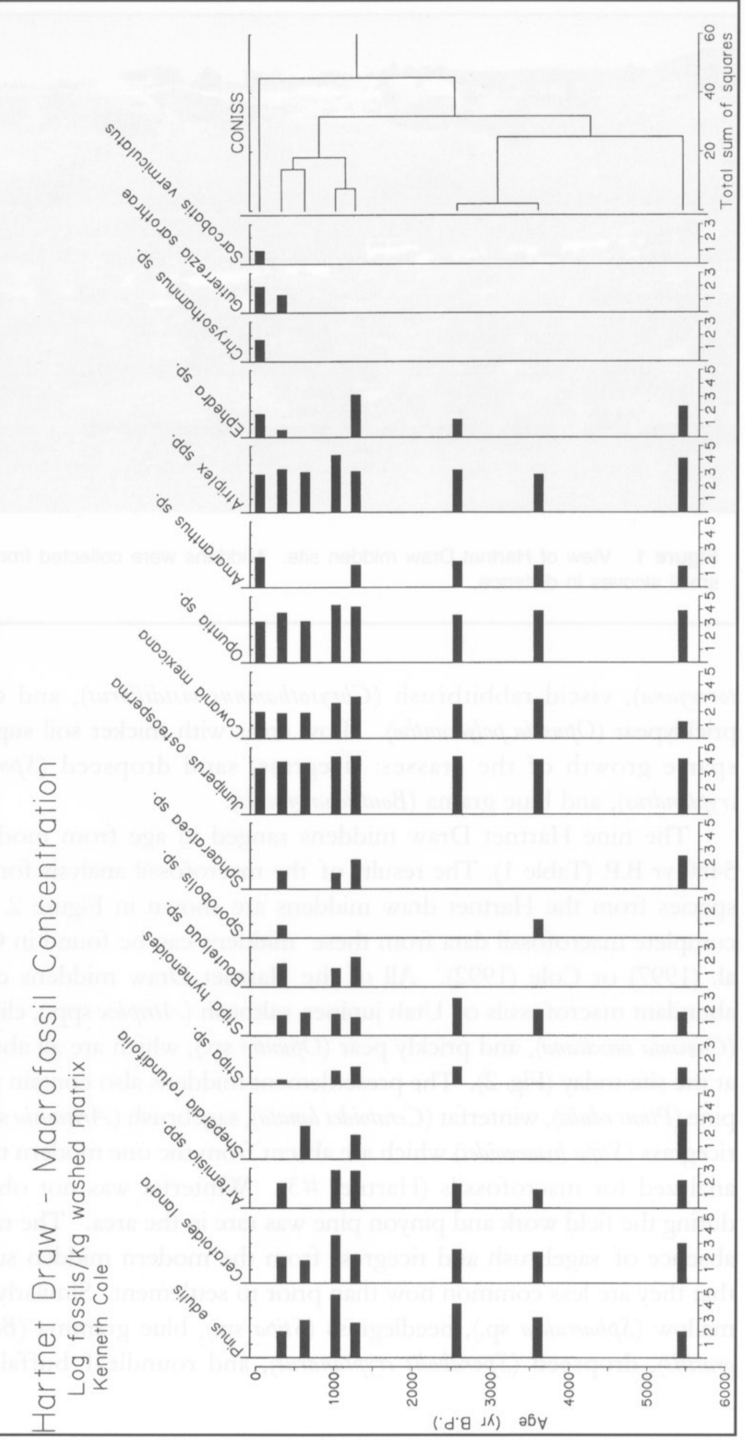

Figure 2. Principal plant macrofossils from Hartnet Draw middens. Fossil values are displayed as Log_{10} of concentration. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).

(*Sheperdia rotundifolia*) are common in the presettlement middens but absent from the one modern midden.

In contrast, Hartnet #3, the modern midden, is the only midden containing viscid rabbitbrush (*Chrysothamnus visidiflorus*), greasewood (*Sarcobatus vermiculatus*), and Russian thistle (*Salsola* sp.) macrofossils. Only the two most recent middens (#3 and #2) contain snakeweed (*Gutterrezia sarothrae*). Rabbitbrush, snakeweed, and Russian thistle are frequent at the site today. The absence of these species from the presettlement middens indicates that these species were formerly absent, or so infrequent as to not be represented. Russian thistle is an introduced Eurasian species.

The cluster analysis (right side of Fig. 2) demonstrates the difference between the modern macrofossil assemblage and the other assemblages. The modern assemblage is the primary branch in the dendrogram even though the single occurrences of rabbitbrush, greasewood, and Russian thistle in the modern midden were disregarded in the analysis.

The results of the pollen analysis (Fig. 3; Murray 1989) are similar to the those from the plant macrofossils. The presettlement middens contained much more pine and sagebrush than the two modern samples (#3 and #4). Similarly, the percentages of grass and buffaloberry pollen were generally higher in the presettlement middens. In contrast, only the two modern middens contained pollen of the exotic Russian thistle and high amounts of juniper pollen. Like the macrofossil cluster analysis, the pollen cluster analysis (right side of Fig. 3) showed that the modern samples are very different from all of the presettlement middens.

Hall's Canyon Middens

Pleistocene Age Middens

Two Pleistocene-age sub-samples were collected from a large midden (Hall's Canyon # 2) located in a high alcove in the Navajo Sandstone near Hall's Canyon (Fig. 4). A picture of the midden itself can be viewed from the web page at: http://www.usgs.nau.edu/methods/middens.html. The front surface of this large midden measures about 2 m wide x 1 m high. The radiocarbon dates from two sub-samples, 28,050±2600 and >39,600 yr B.P., show that this midden is very old. Although the younger radiocarbon sample produced a finite date, dates of this age are less reliable than more recent dates simply because contamination with a minuscule portion of modern material could turn an infinite date (beyond the reach of the radiocarbon method) into a 28,000 year date. As a result, the true age of this midden is not precisely known, but it is definitely ancient, and possibly beyond the resolution of the radiocarbon

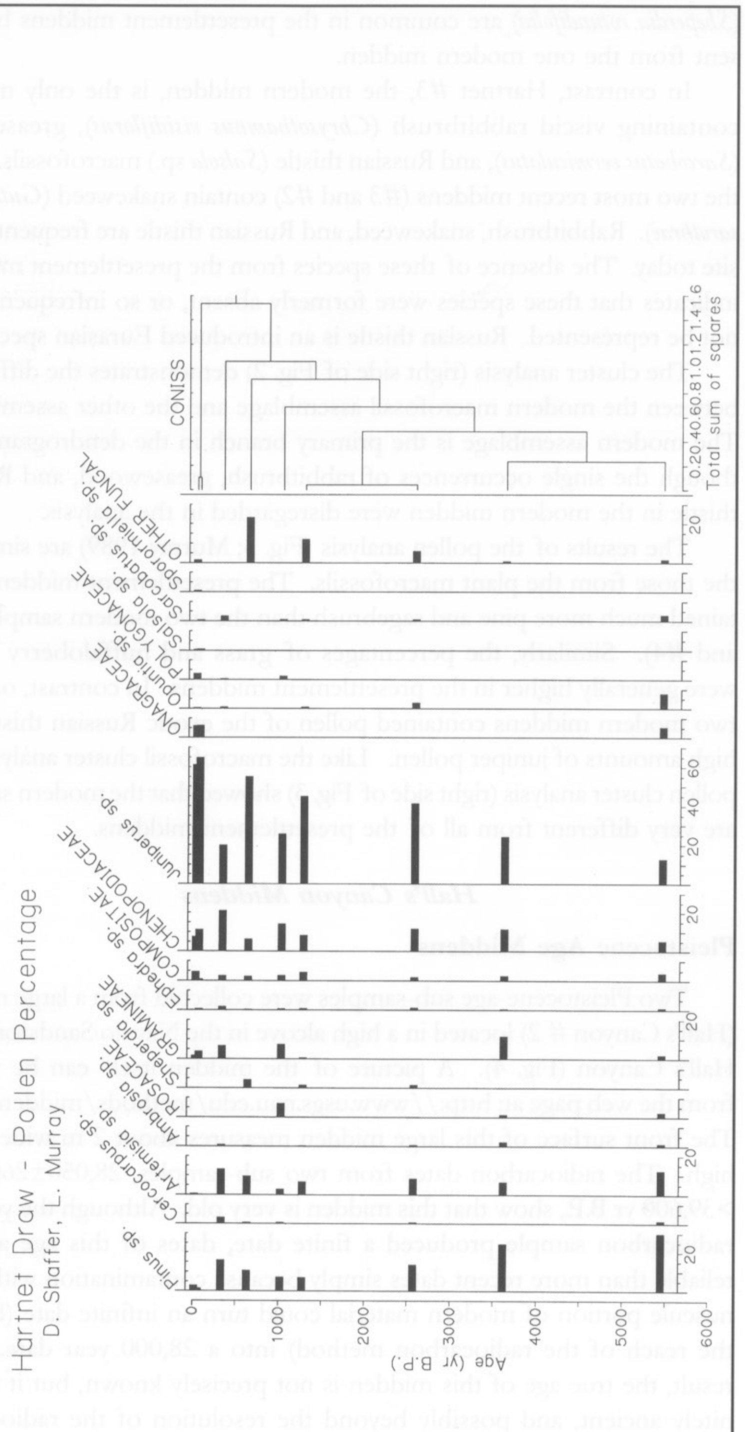

Figure 3. Principal fossil pollen from Hartnet Draw middens. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).

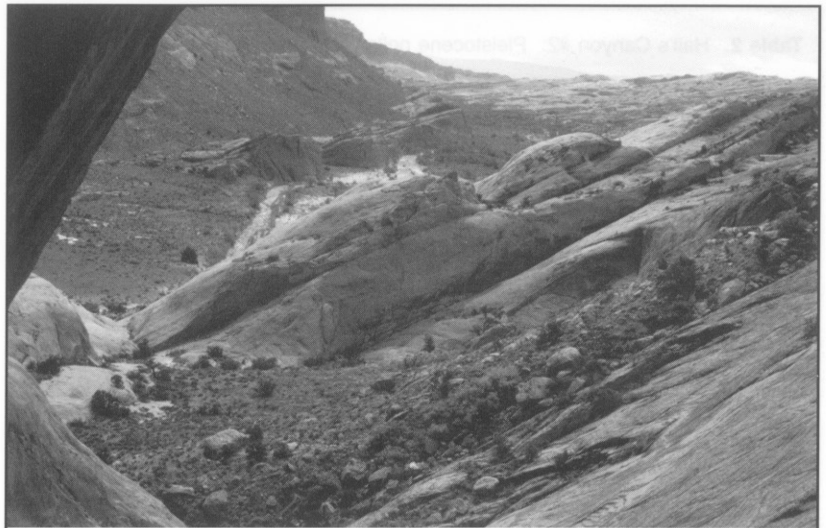

Figure 4. View of Hall's Canyon from alcove in which Hall's Canyon #2 is perched in Navajo Sandstone.

method (> 40,000 to 50,000). The plant macrofossil and pollen content of these samples are shown in Table 2.

Holocene Middens

Nine Holocene middens were collected from several parts of lower Hall's Canyon. Four middens from Hall's Canyon (Baker #3, Hall's Canyon #4, #6, and #7) have a significant probability of dating to either side of 1870 AD and must be considered of Transitional age (Table 1). A fifth midden (Hall's Canyon #8) had only a very small chance of post-dating 1870 AD and is considered Presettlement.

The plant macrofossils from the Hall's Canyon Middens are listed in Table 3 and the major taxa are shown in Figure 5. Sagebrush and winterfat are more concentrated in the Presettlement middens, while cheatgrass (*Bromus tectorum*) occurs in the Transitional and Postsettlement middens. The cluster analysis separates the middens into three groups: Presettlement, Transitional, and Postsettlement. A large difference is apparent between the Presettlement middens and the others. The diversity of taxa between these middens is high, reflecting the microhabitat diversity inherent in an

Table 2. Hall's Canyon #2: Pleistocene pollen and macrofossils.

	Pollen HC2A 28 k	Percent HC2B > 39 k		Macrofossil HC2A 28 k	Percent HC2B > 39 k
Juniperus	10.8	29.7	*Juniperus osteosperma*	73.1	32.8
			Juniperus scopulorum	0.0	1.3
Abies	0.4	0.4			
Picea	0.9	2.7			
Pseudotsuga	5.6	1.9	*Pseudotsuga menziesii*	0.8	39.9
Pinus Total	16.4	5.7	*Pinus flexilis*	0.1	2.2
Ceonot. - Rhamnus	0.4	0.4			
Betulaceae	0.0	0.4	*Ostrya knoltoni*	0.0	0.1
Cercocarpus	0.0	0.8	*Cercocarpus intricatus*	0.2	0.0
Quercus	0.0	1.5			
Ephedra Total	0.9	0.0			
Cheno. \Amar.	5.6	1.5			
Artemesia	27.6	14.1			
Ambrosia	5.6	1.5			
Compositeae	6.0	5.7			
Gramineae	0.0	2.3	*Oryzopsis* sp.	0.0	0.3
Polygonaceae	0.0	0.4			
Sambucus	0.9	0.0			
cf. *Amorpha*	0.0	4.9			
Crucifereae	0.4	4.6			
Labiateae	0.0	0.4			
Leguuminoseae	2.2	4.9			
cf. *Cleome*	11.6	4.6			
Fraxinus	0.0	8.0	cf. *Fraxinus anomala*	0.0	0.3
Juglans	0.0	0.4			
Populus	3.0	2.7			
Salix	0.4	0.0			
Unknowns	6.9	2.6			
Fungal spores	9.1	4.2			
			Yucca cf. *angustissima*	0.0	0.3
			Opuntia sp.	25.8	22.9
Pollen Sum	232	263	Number of Identified Plant Parts	720	1702

area with flat grassland communities adjacent to riparian and rock face habitats.

The results from Hall's Canyon (Fig. 6; Murray 1989) are similar to the macrofossil results. Pine, sagebrush, mountain mahogany (*Cercocarpus*), and Rosaceae are most abundant in the Presettlement middens, while the Postsettlement middens contain Russian thistle and greasewood pollen. The total herbaceous pollen is also more abundant in the Postsettlement middens, perhaps reflecting browsing and other damage to the shrubs.

Table 3. Lower Hall's Canyon plant macrofossils (log_{10} macrofossils per kg washed matrix).

Midden	BS 1	BS 3	HC 4	HC 7	HC 8	N 2	BS 2	HC 6
Age	Modern	20	80	170	265	330	410	105
Artemisia (wood)		1.62				2.28	3	
Artemisia dracunculus		0.84					2.18	
Artemisia filifolia ?			2.65					
Artemisia tridentata							2.74	
Amborsia acanthocarpa			2.47					
Atriplex canescens		0.84	1.07				1.85	2.62
Atriplex	2.34	1.44	3.72	2.53			3.4	
Atriplex confer-type seed			2.25				1.91	
Berberis sp.				2.34		1.33		1.85
Bromus tectorum	1.86			1.3				
Celtis reticulata	2.76	2.16				2.63	1.3	
Cercocarpus intricatus					2.04			
Chrysothamnus sp.								1.15
Coleogyne ramosissima	2.71	2.16	3.28		3.88		2.66	
cf. *Corispermum*			2.35					1.15
Cowania mexicana	1.56		2.59	3.13	2.71		1	2.79
Ephedra sp.		1.92		1.6	2.04	1.81	2.12	1.92
Eurotia lanata	1.86		2.12		2.64	1.93	2.87	1.75
Fraxinus sp.			2.57			2.03		3.1
Gutterezia sp.	1.86	1.84	2.19				3.69	
Juniperus osteosperma	3.34	2.98	3.26	3.95	4.35	2.33	3.73	3.89
Lepidium densiflorum		1.14	1.55			1.63	2.26	1.15
Opuntia sp.	3.73	3.31	2.73	2.38	3.76	2.03	3.7	2.95
Oryzopsis hymenoides	1.56	0.84	1.68		2.34	2.03	2.3	1.15
Phoradendron juniperinum				1.3				
Pinus edulis					3.3			
Plantago sp.			1.07				2.18	2.05
Populus fremontii	1.56	1.54					1.48	
Quercus turbinella					1.74			
Sclerocactus parviflorus	1.56				1.44			
Sporobolis flexosus			1.68			1.33		
Sphaeralcea	1.56						1.85	
Yucca angustissima	2.46	1.79	2.61		2.87		2.23	
small hispid grass	1.14					2.11		

The cluster analysis of the Hall's Canyon pollen samples is very similar to that of the plant macrofossils.

Long Leaf Flat Middens

Two midden samples, one Presettlement and one Postsettlement, were collected from an alcove near Long Leaf Flat adjacent to some

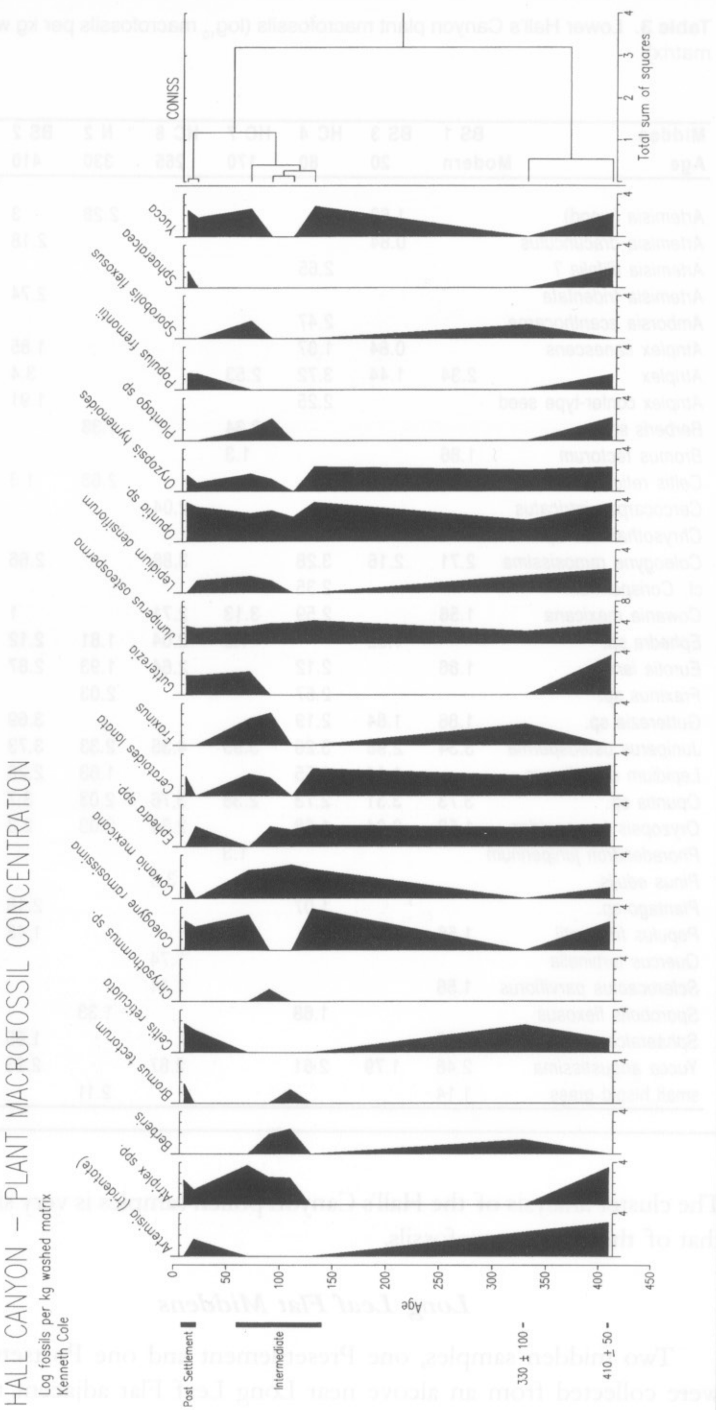

Figure 5. Principal plant macrofossils from Hall's Canyon Holocene middens. Fossil values are displayed as Log_{10} of concentration. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).

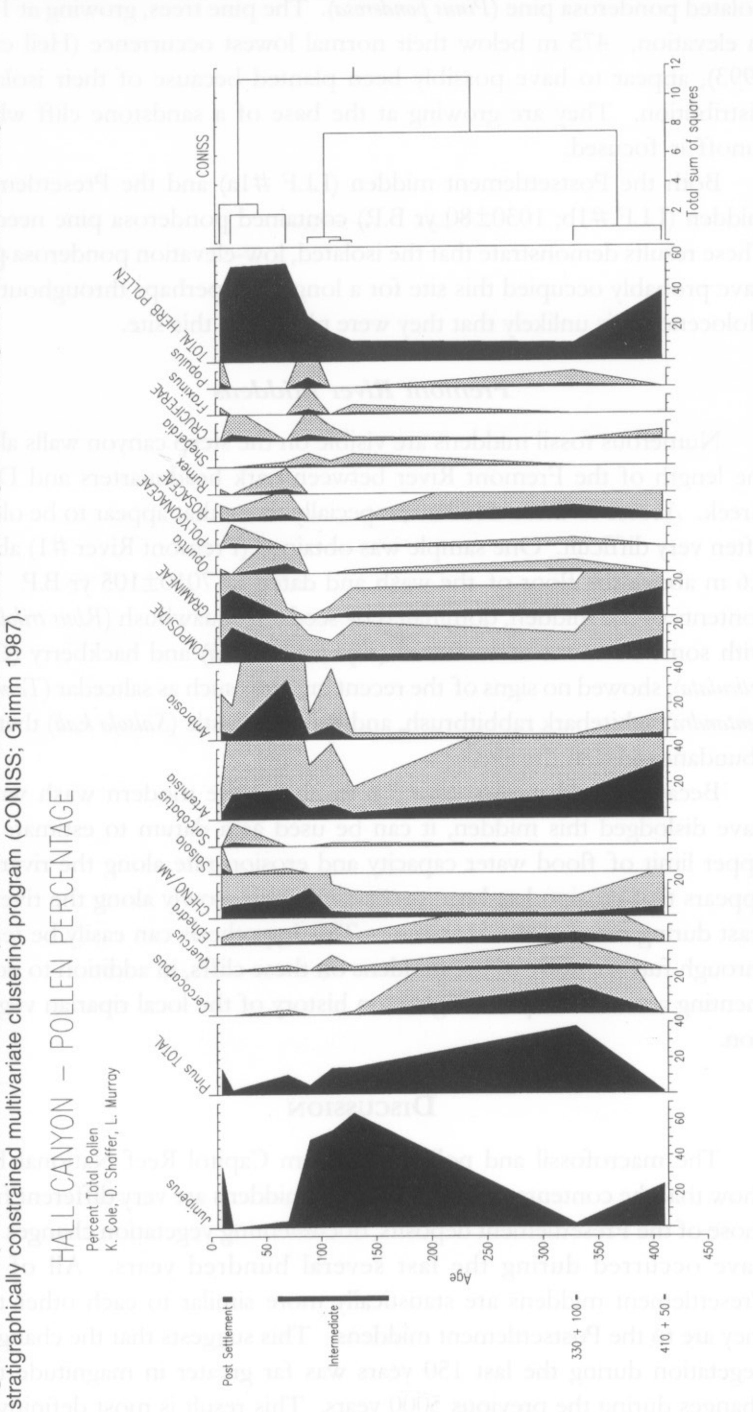

Figure 6. Principal fossil pollen from Hall's Canyon Holocene middens. The cluster analysis (right side of diagram) was created using a stratigraphically constrained multivariate clustering program (CONISS; Grimm 1987).

isolated ponderosa pine (*Pinus ponderosa*). The pine trees, growing at 1980 m elevation, 475 m below their normal lowest occurrence (Heil et al. 1993), appear to have possibly been planted because of their isolated distribution. They are growing at the base of a sandstone cliff where runoff is focused.

Both the Postsettlement midden (LLF #1a) and the Presettlement midden (LLF #1b; 1030±80 yr B.P.) contained ponderosa pine needles. These results demonstrate that the isolated, low-elevation ponderosa pine have probably occupied this site for a long time, perhaps throughout the Holocene. It is unlikely that they were planted at this site.

Fremont River Middens

Numerous fossil middens are visible on the steep canyon walls along the length of the Fremont River between park headquarters and Deep Creek. Access to these middens, especially those that appear to be old, is often very difficult. One sample was obtained (Fremont River #1) about 7.6 m above the floor of the wash and dated to 7010±105 yr B.P. The contents of the midden, dominated by seeds of squawbush (*Rhus trilobata*) with some Fremont cottonwood (*Populus fremontii*) and hackberry (*Celtis reticulata*), showed no signs of the recent invaders such as saltcedar (*Tamarix pentandra*), whitebark rabbitbrush, and Russian thistle (*Salsola kali*) that are abundant today at the site.

Because flood waters over 7.6 m above the modern wash would have dislodged this midden, it can be used as a datum to estimate the upper limit of flood water capacity and erosion rate along the river. It appears that erosion has been proceeding quite slowly along the river, at least during most of the Holocene. This hypothesis can easily be tested through further study of the middens on these cliffs, in addition to documenting a more complete vegetation history of the local riparian vegetation.

DISCUSSION

The macrofossil and pollen data from Capitol Reef National Park show that the contents of Postsettlement middens are very different from those of the Presettlement deposits, documenting vegetation changes that have occurred during the last several hundred years. All of the Presettlement middens are statistically more similar to each other than they are to the Postsettlement middens. This suggests that the change in vegetation during the last 150 years was far greater in magnitude than changes during the previous 5000 years. This result is most definitive at

Hartnet Draw, where the midden series spans 5000 years. In contrast, the Hall's Canyon middens, collected from cliffside ledges, emphasize cliff-dwelling shrubs. The limited time range of the series and the four Transitional age middens (which could not be clearly classified as Pre- or Postsettlement) limit the resolution of the Hall's Canyon data in determining settlement impacts.

The perspective of natural variation emphasizes the extreme severity of the recent vegetation changes. Formerly there was a greater coverage of grasses, winterfat, sagebrush, and pinyon pine, as indicated by the plant macrofossils and pollen. Although the vegetation probably fluctuated continuously throughout the late Holocene, this midden record suggests that previous changes were minor compared to the changes of the last 150 years. The presettlement plant community was likely more similar to the Pinyon-Juniper-Grass Community described by Romme et al. (1993) than the juniper-shrub community present at the Hartnet site today.

Drought History

The reductions in winterfat, pinyon pine, sagebrush, and ricegrass, and increases in juniper, rabbitbrush, and snakeweed might be attributed to droughts during the nineteenth or twentieth centuries. But, an analysis of the last 400 years of drought frequency for southeastern Utah (Cole et al. 1997) using tree-ring data compiled by Fritts (1991), suggests that the droughts of the nineteenth century were not unusually severe when compared to the seventeenth century. Less is known about the climatic variability between 400 and 5000 years ago (prior to this tree-ring record), but it seems unlikely that any climatic event of the last 200 years was sufficient to cause a change with no precedent during the previous 5000 years. Drought undoubtedly did assist in some of the dramatic vegetation changes of the last 200 years, but did not set the stage for them. This would require an event unprecedented during the previous 5000 years.

Fire History

Some of the changes recorded in the middens may have been caused by changes in fire regime. The recent increase in juniper could result from a decrease in fire frequency caused by the elimination of the grassy fuels by grazing. But this does little to explain the shift from palatable to non-palatable species or the reductions of pinyon pine, sagebrush, and buffaloberry just at the time that fire frequency would decrease.

Grazing Impacts

Impacts from introduced herbivores, especially large sheep herds in the late nineteenth and early twentieth centuries, are the most likely cause of the recent radical vegetation changes. The introduction of sheep, goats, cattle, and horses was without precedent during the previous 5000 years. Overall, the vegetation has shifted from palatable forage (grasses, winterfat, and buffaloberry), to less palatable forage (rabbitbrush, snakeweed, and greasewood). Rabbitbrush and snakeweed are typical invaders of overgrazed range (Benson and Darrow 1981, Heil et al. 1993, Cronquist et al. 1994).

Other studies conducted on grazing at Capitol Reef support this conclusion. Heil et al. (1993), in a survey of the vegetation of Capitol Reef National Park, state that, "Some of the most preferred plant species (for grazers), e.g., *Ceratoides lanata* and *Stipa comata*, may have been locally extirpated by grazing." This is demonstrated by the packrat midden series from Hartnet Draw site.

An analysis of grass opal phytoliths in buried soil horizons at Capitol Reef shows a reduction of palatable grass species over the last several hundred years (Fisher et al. 1995). In general, opal phytoliths from warm season grasses have recently increased at the expense of cool season grasses. The authors attribute this change to the winter grazing that has taken place on these lands.

In a comparison of bird usage of grazed areas near the Hartnet site with similar rarely grazed areas nearby, Willey (1994) found that grazed areas were significantly lower in bird species richness. He attributed the difference to a less complex structure in the grazed vegetation. His vegetative comparisons showed higher grass coverage in the rarely grazed areas, especially a higher coverage of ricegrass, further supporting the results of this study.

An analysis of riparian areas (Barth and McCullough 1988) indicated that dramatic changes had occurred prior to the Taylor Grazing Act of 1934. Forage plants were heavily used, and in many instances cover was entirely removed. Recent grazing has perpetuated this removal or reduction of species and inhibited potential recovery. In a lightly grazed area palatable shrubs and grasses have increased significantly.

Pinyon Pine Decline

Dramatic declines in pinyon, sagebrush, and buffaloberry occurring within the most recent several hundred years were probably also caused by grazing, but the effects on these species are less well understood. Pinyon-juniper woodlands have been reported to have increased in the

Great Basin during the historic period, especially when comparative photographic techniques which can not discriminate between pinyon and juniper are used (West et al. 1975, Tausch et al. 1981). This increase in pinyon-juniper woodlands is thought to have been caused by reduced competition from grasses and forbs, which were eliminated by grazing and by consequent reductions in fire frequency. However, studies discriminating between pinyon and juniper do not portray identical histories for both species. Juniper populations have been expanding rapidly, and in places such as western Oregon where it is not associated with pinyon, the expansion is clear, although there are numerous possible causes (Miller and Wigand 1994). Pine and sagebrush both declined while juniper dramatically increased during the settlement period at Peck's Lake, Arizona (Davis 1987). A study of tree age structure on a presently ungrazed site in the Needle Range in southwestern Utah found that during the nineteenth century many juniper and few pinyon were established. By 1915, the situation had reversed with far more pinyon becoming established in this century (Tausch and West 1988). These results demonstrate that pinyon and juniper respond differently to changing regimes of grazing, fire, or climate. The observation that heavy grazing causes an expansion of pinyon-juniper woodland (West et al. 1975) does not equate to the expansion of both species in all habitats.

The results of Tausch and West (1988) and those of the present study, suggest that pinyon may have been greatly reduced during the late nineteenth century/early twentieth century by the large numbers of sheep grazing the landscape during drought. Pinyon may now be recovering part of its former range, assisted by the absence of fire. Sheep readily consume pine needles and strip pine bark even in the absence of drought conditions (Anderson et al. 1985). Sheep accomplished the near complete elimination of the Bishop pine forest (*Pinus muricata*) on Santa Cruz Island, California, where they were not fenced out (Hobbs 1980). Cattle will also browse some pine when it is available (Pfister and Adams 1993), but are less likely to consume entire forests. This suggests that knowledge of the effects of cattle grazing at present stocking levels forms an inadequate basis for judging the effects of an overstocked sheep range during the droughts of the late nineteenth century.

Sagebrush populations may have a similar history despite observation of increases in sagebrush caused by the removal of their grass competitors (Young et al. 1978). Although sagebrush may be increasing on land presently grazed by cattle, this is not an appropriate analog for intense nineteenth century sheep grazing. Sagebrush is consumed by sheep during droughts. During the late nineteenth century, sheep severely reduced the populations of California sagebrush (*Artemisia californica*) on Santa Rosa Island, California, after first consuming the grass (Cole and Liu 1994).

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